**Open Shortest Path First**

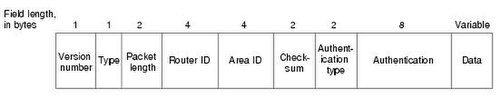
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**Open Shortest Path First** (**OSPF**) is a [routing protocol](https://en.wikipedia.org/wiki/Routing_protocol) for [Internet Protocol](https://en.wikipedia.org/wiki/Internet_Protocol) (IP) networks. It uses a [link state routing](https://en.wikipedia.org/wiki/Link-state_routing_protocol) (LSR) algorithm and falls into the group of [interior gateway protocols](https://en.wikipedia.org/wiki/Interior_gateway_protocol) (IGPs), operating within a single [autonomous system](https://en.wikipedia.org/wiki/Autonomous_system_(Internet)) (AS). It is defined as OSPF Version 2 in [RFC 2328](https://tools.ietf.org/html/rfc2328) (1998) for [IPv4](https://en.wikipedia.org/wiki/IPv4).[[1]](https://en.wikipedia.org/wiki/Open_Shortest_Path_First#cite_note-rfc2328-1) The updates for [IPv6](https://en.wikipedia.org/wiki/IPv6) are specified as OSPF Version 3 in [RFC 5340](https://tools.ietf.org/html/rfc5340) (2008).[[2]](https://en.wikipedia.org/wiki/Open_Shortest_Path_First#cite_note-rfc5340-2) OSPF supports the [Classless Inter-Domain Routing](https://en.wikipedia.org/wiki/Classless_Inter-Domain_Routing) (CIDR) addressing model.

OSPF is a widely used IGP in large [enterprise networks](https://en.wikipedia.org/wiki/Enterprise_network). [IS-IS](https://en.wikipedia.org/wiki/IS-IS), another LSR-based protocol, is more common in large [service provider](https://en.wikipedia.org/wiki/Network_service_provider) networks.

## Operation

[](https://en.wikipedia.org/wiki/File:CT844602.jpg)

OSPF packet format

OSPF was designed as an [interior gateway protocol](https://en.wikipedia.org/wiki/Interior_gateway_protocol) (IGP), for use in an [autonomous system](https://en.wikipedia.org/wiki/Autonomous_system_(Internet)) such as a [local area network](https://en.wikipedia.org/wiki/Local_area_network) (LAN). It implements [Dijkstra's algorithm](https://en.wikipedia.org/wiki/Dijkstra%27s_algorithm), also known as the shortest path first (SPF) algorithm. As a [link-state routing protocol](https://en.wikipedia.org/wiki/Link-state_routing_protocol) it was based on the link-state algorithm developed for the [ARPANET](https://en.wikipedia.org/wiki/ARPANET) in 1980 and the [IS-IS](https://en.wikipedia.org/wiki/IS-IS) routing protocol. OSPF was first standardized in 1989 as [RFC 1131](https://tools.ietf.org/html/rfc1131), which is now known as OSPF version 1. The development work for OSPF prior to its codification as open standard was undertaken largely by the [Digital Equipment Corporation](https://en.wikipedia.org/wiki/Digital_Equipment_Corporation), which developed its own proprietary [DECnet](https://en.wikipedia.org/wiki/DECnet) protocols.[[3]](https://en.wikipedia.org/wiki/Open_Shortest_Path_First#cite_note-3)

Routing protocols like OSPF calculate the *shortest* route to a destination through the network based on an algorithm. The first routing protocol that was widely implemented, the [Routing Information Protocol](https://en.wikipedia.org/wiki/Routing_Information_Protocol) (RIP), calculated the shortest route based on hops, that is the number of [routers](https://en.wikipedia.org/wiki/Router_(computing)) that an [IP packet](https://en.wikipedia.org/wiki/IP_packet_(disambiguation)) had to traverse to reach the destination host. RIP successfully implemented [dynamic routing](https://en.wikipedia.org/wiki/Dynamic_routing), where routing tables change if the [network topology](https://en.wikipedia.org/wiki/Network_topology) changes. But RIP did not adapt its routing according to changing network conditions, such as [data-transfer rate](https://en.wikipedia.org/wiki/Data-rate_units). Demand grew for a dynamic routing protocol that could calculate the *fastest* route to a destination. OSPF was developed so that the shortest path through a network was calculated based on the *cost* of the route, taking into account [bandwidth](https://en.wikipedia.org/wiki/Bandwidth_(computing)), delay and load.[[4]](https://en.wikipedia.org/wiki/Open_Shortest_Path_First#cite_note-4) Therefore OSPF undertakes route cost calculation on the basis of link-cost parameters, which can be weighted by the administrator. OSPF was quickly adopted because it became known for reliably calculating routes through large and complex local area networks.[[5]](https://en.wikipedia.org/wiki/Open_Shortest_Path_First#cite_note-5)

As a link-state routing protocol, OSPF maintains link-state databases, which are really network topology maps, on every router on which it is implemented. The *state* of a given route in the network is the cost, and OSPF algorithm allows every router to calculate the cost of the routes to any given reachable destination.[[6]](https://en.wikipedia.org/wiki/Open_Shortest_Path_First#cite_note-6) Unless the administrator has made a configuration, the link cost of a path connected to a router is determined by the [bit rate](https://en.wikipedia.org/wiki/Bit_rate) (1 Gbit/s, 10 Gbit/s, etc) of the interface. A router interface with OSPF will then advertise its link cost to neighboring routers through multicast, known as the *hello procedure*.[[7]](https://en.wikipedia.org/wiki/Open_Shortest_Path_First#cite_note-7) All routers with OSPF implementation keep sending hello packets, and thus changes in the cost of their links become known to neighboring routers.[[8]](https://en.wikipedia.org/wiki/Open_Shortest_Path_First#cite_note-8) The information about the cost of a link, that is the speed of a point to point connection between two routers, is then cascaded through the network because OSPF routers advertise the information they receive from one neighboring router to all other neighboring routers. This process of flooding link state information through the network is known as *synchronization*. Based on this information, all routers with OSPF implementation continuously update their link state databases with information about the network topology and adjust their routing tables.[[9]](https://en.wikipedia.org/wiki/Open_Shortest_Path_First#cite_note-9)

An OSPF network can be structured, or subdivided, into routing *areas* to simplify administration and optimize traffic and resource utilization. Areas are identified by 32-bit numbers, expressed either simply in decimal, or often in the same [dot-decimal notation](https://en.wikipedia.org/wiki/Dot-decimal_notation) used for IPv4 addresses. By convention, area 0 (zero), or 0.0.0.0, represents the core or *backbone* area of an OSPF network. While the identifications of other areas may be chosen at will; administrators often select the IP address of a main router in an area as the area identifier. Each additional area must have a connection to the OSPF backbone area. Such connections are maintained by an interconnecting router, known as an area border router (ABR). An ABR maintains separate link-state databases for each area it serves and maintains [summarized routes](https://en.wikipedia.org/wiki/Route_summarization) for all areas in the network.

OSPF detects changes in the topology, such as link failures, and [converges](https://en.wikipedia.org/wiki/Convergence_(routing)) on a new loop-free routing structure within seconds.[[10]](https://en.wikipedia.org/wiki/Open_Shortest_Path_First#cite_note-10)

OSPF has become a popular dynamic routing protocol. Other commonly used dynamic routing protocols are the RIPv2 and the [Border Gateway Protocol](https://en.wikipedia.org/wiki/Border_Gateway_Protocol) (BGP). [[11]](https://en.wikipedia.org/wiki/Open_Shortest_Path_First#cite_note-11) Today [routers](https://en.wikipedia.org/wiki/Router_(computing)) support at least one interior gateway protocol to advertise their [routing tables](https://en.wikipedia.org/wiki/Routing_tables) within a local area network. Frequently implemented interior gateway protocols besides OSPF are RIPv2, IS-IS, and [EIGRP](https://en.wikipedia.org/wiki/EIGRP) (Enhanced Interior Gateway Routing Protocol). [[12]](https://en.wikipedia.org/wiki/Open_Shortest_Path_First#cite_note-12).

## Router relationships

OSPF supports complex networks with multiple routers, including backup routers, to balance traffic load on multiple links to other subnets. Neighboring routers in the same [broadcast domain](https://en.wikipedia.org/wiki/Broadcast_domain) or at each end of a [point-to-point link](https://en.wikipedia.org/wiki/Point-to-point_communication_(telecommunications)) communicate with each other via the OSPF protocol. Routers form *adjacencies* when they have detected each other. This detection is initiated when a router identifies itself in a *Hello* protocol packet. Upon acknowledgment, this establishes a *two-way state* and the most basic relationship. The routers in an Ethernet or Frame Relay network select a *Designated Router* (DR) and a *Backup Designated Router* (BDR) which act as a hub to reduce traffic between routers. OSPF uses both [unicast](https://en.wikipedia.org/wiki/Unicast) and multicast transmission modes to send "Hello" packets and link-state updates.

As a link-state routing protocol, OSPF establishes and maintains neighbor relationships for exchanging routing updates with other routers. The neighbor relationship table is called an *adjacency database*. Two OSPF routers are neighbors if they are members of the same subnet and share the same area ID, subnet mask, timers and authentication. In essence, OSPF neighborship is a relationship between two routers that allow them to see and understand each other but nothing more. OSPF neighbors do not exchange any routing information – the only packets they exchange are Hello packets. OSPF adjacencies are formed between selected neighbors and allow them to exchange routing information. Two routers must first be neighbors and only then, can they become adjacent. Two routers become adjacent if at least one of them is Designated Router or Backup Designated Router (on multiaccess type networks), or they are interconnected by a point-to-point or point-to-multipoint network type. For forming a neighbor relationship between, the interfaces used to form the relationship must be in the same OSPF area. While an interface may be configured to belong to multiple areas, this is generally not practiced. When configured in a second area, an interface must be configured as a secondary interface.

### Adjacency state machine

Each OSPF router within a network communicates with other neighboring routers on each connecting interface to establish the states of all adjacencies. Every such communication sequence is a separate *conversation* identified by the pair of router IDs of the communicating neighbors. [RFC 2328](https://tools.ietf.org/html/rfc2328) specifies the protocol for initiating these conversations (*Hello Protocol*) and for establishing full adjacencies (*Database Description Packets*, *Link State Request Packets*). During its course, each router conversation transitions through a maximum of eight conditions defined by a state machine:[[1]](https://en.wikipedia.org/wiki/Open_Shortest_Path_First#cite_note-rfc2328-1)[[13]](https://en.wikipedia.org/wiki/Open_Shortest_Path_First#cite_note-13)

1. Down: The state *down* represents the initial state of a conversation when no information has been exchanged and retained between routers with the Hello Protocol.
2. Attempt: The *Attempt* state is similar to the *Down* state, except that a router is in the process of efforts to establish a conversation with another router, but is only used on [NBMA](https://en.wikipedia.org/wiki/Non-broadcast_multiple-access_network) networks.
3. Init: The *Init* state indicates that a HELLO packet has been received from a neighbor, but the router has not established a two-way conversation.
4. 2-Way: The *2-Way* state indicates the establishment of a bidirectional conversation between two routers. This state immediately precedes the establishment of adjacency. This is the lowest state of a router that may be considered as a Designated Router.
5. ExStart: The *ExStart* state is the first step of adjacency of two routers.
6. Exchange: In the *Exchange* state, a router is sending its link-state database information to the adjacent neighbor. At this state, a router is able to exchange all OSPF routing protocol packets.
7. Loading: In the *Loading* state, a router requests the most recent [Link-state advertisements](https://en.wikipedia.org/wiki/Link-state_advertisement) (LSAs) from its neighbor discovered in the previous state.
8. Full: The *Full* state concludes the conversation when the routers are fully adjacent, and the state appears in all router- and network-LSAs. The link state databases of the neighbors are fully synchronized.

### OSPF messages

Unlike other routing protocols, OSPF does not carry data via a transport protocol, such as the [User Datagram Protocol](https://en.wikipedia.org/wiki/User_Datagram_Protocol) (UDP) or the [Transmission Control Protocol](https://en.wikipedia.org/wiki/Transmission_Control_Protocol) (TCP). Instead, OSPF forms IP datagrams directly, packaging them using protocol number 89 for the [IP Protocol field](https://en.wikipedia.org/wiki/List_of_IP_protocol_numbers). OSPF defines five different message types, for various types of communication:

Hello

*Hello* messages are used as a form of greeting, to allow a router to discover other adjacent routers on its local links and networks. The messages establish relationships between neighboring devices (called adjacencies) and communicate key parameters about how OSPF is to be used in the autonomous system or area. During normal operation, routers send hello messages to their neighbors at regular intervals (the *hello interval*); if a router stops receiving hello messages from a neighbor, after a set period (the *dead interval*) the router will assume the neighbor has gone down.

Database Description (*DBD*)

*Database description* messages contain descriptions of the topology of the autonomous system or area. They convey the contents of the link-state database (LSDB) for the area from one router to another. Communicating a large LSDB may require several messages to be sent by having the sending device designated as a master device and sending messages in sequence, with the slave (recipient of the LSDB information) responding with acknowledgments.

Link State Request (*LSR*)

*Link state request* messages are used by one router to request updated information about a portion of the LSDB from another router. The message specifies the link(s) for which the requesting device wants more current information.

Link State Update (*LSU*)

*Link-state update* messages contain updated information about the state of certain links on the LSDB. They are sent in response to a Link State Request message, and also broadcast or multicast by routers on a regular basis. Their contents are used to update the information in the LSDBs of routers that receive them.

Link State Acknowledgment (*LSAck*)

*Link-state acknowledgment* messages provide reliability to the link-state exchange process, by explicitly acknowledging receipt of a Link State Update message.

## OSPF areas

An OSPF network can be divided into *areas* that are logical groupings of hosts and networks. An area includes its connecting router having interfaces connected to the network. Each area maintains a separate link-state database whose information may be summarized towards the rest of the network by the connecting router. Thus, the topology of an area is unknown outside the area. This reduces the routing traffic between parts of an autonomous system.

Areas are uniquely identified with 32-bit numbers. The area identifiers are commonly written in the dot-decimal notation, familiar from IPv4 addressing. However, they are not IP addresses and may duplicate, without conflict, any IPv4 address. The area identifiers for IPv6 implementations (OSPFv3) also use 32-bit identifiers written in the same notation. When dotted formatting is omitted, most implementations expand area *1* to the area identifier *0.0.0.1*, but some have been known to expand it as *1.0.0.0*.[[*citation needed*](https://en.wikipedia.org/wiki/Wikipedia:Citation_needed)]

OSPF defines several special area types:

### Backbone area

The backbone area (also known as *area 0* or *area 0.0.0.0*) forms the core of an OSPF network. All other areas are connected to it, either directly or through other routers. Inter-area routing happens via routers connected to the backbone area and to their own associated areas. It is the logical and physical structure for the 'OSPF domain' and is attached to all nonzero areas in the OSPF domain. Note that in OSPF the term Autonomous System Boundary Router (ASBR) is historic, in the sense that many OSPF domains can coexist in the same Internet-visible autonomous system, [RFC 1996](https://tools.ietf.org/html/rfc1996).[[14]](https://en.wikipedia.org/wiki/Open_Shortest_Path_First#cite_note-14)[[15]](https://en.wikipedia.org/wiki/Open_Shortest_Path_First#cite_note-15)

The backbone area is responsible for distributing routing information between non-backbone areas. The backbone must be contiguous, but it does not need to be physically contiguous; backbone connectivity can be established and maintained through the configuration of virtual links.

All OSPF areas must connect to the backbone area. This connection, however, can be through a virtual link. For example, assume area 0.0.0.1 has a physical connection to area 0.0.0.0. Further assume that area 0.0.0.2 has no direct connection to the backbone, but this area does have a connection to area 0.0.0.1. Area 0.0.0.2 can use a virtual link through the *transit area* 0.0.0.1 to reach the backbone. To be a transit area, an area has to have the transit attribute, so it cannot be stubby in any way.

### Stub area

A stub area is an area that does not receive route advertisements external to the AS and routing from within the area is based entirely on a default route. An ABR deletes type 4, 5 LSAs from internal routers, sends them a default route of 0.0.0.0 and turns itself into a default gateway. This reduces LSDB and routing table size for internal routers.

Modifications to the basic concept of stub area have been implemented by systems vendors, such as the *totally stubby area* (TSA) and the *not-so-stubby area* (NSSA), both an extension in [Cisco Systems](https://en.wikipedia.org/wiki/Cisco_Systems) routing equipment.

#### Not-so-stubby area

A *not-so-stubby area* (NSSA) is a type of stub area that can import autonomous system external routes and send them to other areas, but still cannot receive AS-external routes from other areas.[[16]](https://en.wikipedia.org/wiki/Open_Shortest_Path_First#cite_note-rfc3101-16) NSSA is an extension of the stub area feature that allows the injection of external routes in a limited fashion into the stub area. A case study simulates an NSSA getting around the Stub Area problem of not being able to import external addresses. It visualizes the following activities: the ASBR imports external addresses with a type 7 LSA, the ABR converts a type 7 LSA to type 5 and floods it to other areas, the ABR acts as an "ASBR" for other areas. The ASBRs do not take type 5 LSAs and then convert to type 7 LSAs for the area.

#### Proprietary extensions

Several vendors (Cisco, Allied Telesis, Juniper, Alcatel-Lucent, Huawei, Quagga), implement the two extensions below for stub and not-so-stubby areas. Although not covered by RFC standards, they are considered by many to be standard features in OSPF implementations.

Totally stubby area

A *totally stubby area* is similar to a stub area. However, this area does not allow *summary* routes in addition to not having *external* routes, that is, *inter-area* (IA) routes are not summarized into totally stubby areas. The only way for traffic to get routed outside the area is a default route which is the only Type-3 LSA advertised into the area. When there is only one route out of the area, fewer routing decisions have to be made by the route processor, which lowers system resource utilization.

Occasionally, it is said that a TSA can have only one ABR.[[17]](https://en.wikipedia.org/wiki/Open_Shortest_Path_First#cite_note-17)

NSSA totally stubby area

An addition to the standard functionality of an NSSA, the *totally stubby NSSA* is an NSSA that takes on the attributes of a TSA, meaning that type 3 and 4 summary routes are not flooded into this type of area. It is also possible to declare an area both totally stubby and not-so-stubby, which means that the area will receive only the default route from area 0.0.0.0, but can also contain an autonomous system boundary router (ASBR) that accepts external routing information and injects it into the local area, and from the local area into area 0.0.0.0.

Redistribution into an NSSA area creates a special type of LSA known as type 7, which can exist only in an NSSA area. An NSSA ASBR generates this LSA, and an NSSA ABR router translates it into type 5 LSA which gets propagated into the OSPF domain.

A newly acquired subsidiary is one example of where it might be suitable for an area to be simultaneously not-so-stubby and totally stubby if the practical place to put an ASBR is on the edge of a totally stubby area. In such a case, the ASBR does send externals into the totally stubby area, and they are available to OSPF speakers within that area. In Cisco's implementation, the external routes can be summarized before injecting them into the totally stubby area. In general, the ASBR should not advertise default into the TSA-NSSA, although this can work with extremely careful design and operation, for the limited special cases in which such an advertisement makes sense.

By declaring the totally stubby area as NSSA, no external routes from the backbone, except the default route, enter the area being discussed. The externals do reach area 0.0.0.0 via the TSA-NSSA, but no routes other than the default route enter the TSA-NSSA. Routers in the TSA-NSSA send all traffic to the ABR, except to routes advertised by the ASBR.

### Transit area

A transit area is an area with two or more OSPF border routers and is used to pass network traffic from one adjacent area to another. The transit area does not originate this traffic and is not the destination of such traffic.

## Router types

OSPF defines the following overlapping categories of routers:

Internal router (IR)

An *internal router* has all its interfaces belonging to the same area.

Area border router (ABR)

An *area border router* is a router that connects one or more areas to the main backbone network. It is considered a member of all areas it is connected to. An ABR keeps multiple [instances](https://en.wikipedia.org/wiki/Instance_(computer_science)) of the link-state database in memory, one for each area to which that router is connected.

Backbone router (BR)

A *backbone router* has an interface to the backbone area. Backbone routers may also be area routers, but do not have to be.

Autonomous system boundary router (ASBR)

An *autonomous system boundary router* is a router that is connected by using more than one routing protocol and that exchanges routing information with routers autonomous systems. ASBRs typically also run an exterior routing protocol (e.g., [BGP](https://en.wikipedia.org/wiki/BGP)), or use static routes, or both. An ASBR is used to [distribute routes](https://en.wikipedia.org/wiki/Route_redistribution) received from other, external ASs throughout its own autonomous system. An ASBR creates External LSAs for external addresses and floods them to all areas via ABR. Routers in other areas use ABRs as next hops to access external addresses. Then ABRs forward packets to the ASBR that announces the external addresses.

The router type is an attribute of an OSPF process. A given physical router may have one or more OSPF processes. For example, a router that is connected to more than one area, and which receives routes from a BGP process connected to another AS, is both an area border router and an autonomous system boundary router.

Each router has an identifier, customarily written in the dotted-decimal format (e.g., 1.2.3.4) of an IP address. This identifier must be established in every OSPF instance. If not explicitly configured, the highest logical IP address will be duplicated as the router identifier. However, since the router identifier is not an IP address, it does not have to be a part of any routable subnet in the network, and often isn't to avoid confusion.

## Router attributes

In addition to the four router types, OSPF uses the terms *designated router* (DR) and *backup designated router* (BDR), which are attributes of a router interface.

Designated router

A *designated router* (DR) is the router interface elected among all routers on a particular multiaccess network segment, generally assumed to be broadcast multiaccess. Special techniques, often vendor-dependent, may be needed to support the DR function on non-broadcast multiaccess (NBMA) media. It is usually wise to configure the individual virtual circuits of an NBMA subnet as individual point-to-point lines; the techniques used are implementation-dependent.

Backup designated router

A *backup designated router* (BDR) is a router that becomes the designated router if the current designated router has a problem or fails. The BDR is the OSPF router with the second-highest priority at the time of the last election.

A given router can have some interfaces that are designated (DR) and others that are backup designated (BDR), and others that are non-designated. If no router is a DR or a BDR on a given subnet, the BDR is first elected, and then a second election is held for the DR.[[1]](https://en.wikipedia.org/wiki/Open_Shortest_Path_First#cite_note-rfc2328-1):75 The DR is elected based on the following default criteria:

* If the priority setting on an OSPF router is set to 0, that means it can NEVER become a DR or BDR.
* When a DR fails and the BDR takes over, there is another election to see who becomes the replacement BDR.
* The router sending the Hello packets with the highest priority wins the election.
* If two or more routers tie with the highest priority setting, the router sending the Hello with the highest RID (Router ID) wins. NOTE: a RID is the highest logical (loopback) IP address configured on a router, if no logical/loopback IP address is set then the router uses the highest IP address configured on its active interfaces (e.g. *192.168.0.1* would be higher than *10.1.1.2*).
* Usually the router with the second-highest priority number becomes the BDR.
* The priority values range between 0 – 255,[[18]](https://en.wikipedia.org/wiki/Open_Shortest_Path_First#cite_note-18) with a higher value increasing its chances of becoming DR or BDR.
* If a higher priority OSPF router comes online after the election has taken place, it will not become DR or BDR until (at least) the DR and BDR fail.
* If the current DR 'goes down' the current BDR becomes the new DR and a new election takes place to find another BDR. If the new DR then 'goes down' and the original DR is now available, still previously chosen BDR will become DR.

DR's exist for the purpose of reducing network traffic by providing a source for routing updates. The DR maintains a complete topology table of the network and sends the updates to the other routers via multicast. All routers in a multi-access network segment will form a slave/master relationship with the DR. They will form adjacencies with the DR and BDR only. Every time a router sends an update, it sends it to the DR and BDR on the multicast address *224.0.0.6*. The DR will then send the update out to all other routers in the area, to the multicast address *224.0.0.5*. This way all the routers do not have to constantly update each other, and can rather get all their updates from a single source. The use of multicasting further reduces the network load. DRs and BDRs are always setup/elected on OSPF broadcast networks. DR's can also be elected on NBMA (Non-Broadcast Multi-Access) networks such as Frame Relay or ATM. DRs or BDRs are not elected on point-to-point links (such as a point-to-point WAN connection) because the two routers on either side of the link must become fully adjacent and the bandwidth between them cannot be further optimized. DR and non-DR routers evolve from 2-way to full adjacency relationships by exchanging DD, Request, and Update.

## Routing metrics

OSPF uses *path cost* as its basic routing metric, which was defined by the standard not to equate to any standard value such as speed, so the network designer could pick a metric important to the design. In practice, it is determined by the speed (bandwidth) of the interface addressing the given route, although that tends to need network-specific scaling factors now that links faster than 25 Mbit/s are common. Cisco uses a metric like (108 bit/s)/bandwidth (the reference value, 108 bit/s by default, can be adjusted). So, a 100 Mbit/s link will have a cost of 1, a 10 Mbit/s a cost of 10 and so on. But for links faster than 100 Mbit/s, the cost would be <1.

Metrics, however, are only directly comparable when of the same type. Four types of metrics are recognized. In decreasing preference, these types are (for example, an intra-area route is always preferred to an external route regardless of metric):

1. Intra-area
2. Inter-area
3. External Type 1, which includes both the external path cost and the sum of internal path costs to the ASBR that advertises the route,[[19]](https://en.wikipedia.org/wiki/Open_Shortest_Path_First#cite_note-19)
4. External Type 2, the value of which is solely that of the external path cost,

## OSPF v3

OSPF version 3 introduces modifications to the IPv4 implementation of the protocol.[[2]](https://en.wikipedia.org/wiki/Open_Shortest_Path_First#cite_note-rfc5340-2) Except for virtual links, all neighbor exchanges use IPv6 link-local addressing exclusively. The IPv6 protocol runs per link, rather than based on the [subnet](https://en.wikipedia.org/wiki/Subnetwork). All IP prefix information has been removed from the link-state advertisements and from the *hello* discovery packet making OSPFv3 essentially protocol-independent. Despite the expanded IP addressing to 128-bits in IPv6, area and router identifications are still based on 32-bit numbers.

## OSPF Extensions

### Traffic engineering

OSPF-TE is an extension to OSPF extending the expressivity to allow for traffic engineering and use on non-IP networks.[[20]](https://en.wikipedia.org/wiki/Open_Shortest_Path_First#cite_note-20) Using OSPF-TE, more information about the topology can be exchanged using opaque LSA carrying [type-length-value](https://en.wikipedia.org/wiki/Type-length-value) elements. These extensions allow OSPF-TE to run completely out of band of the data plane network. This means that it can also be used on non-IP networks, such as optical networks.

OSPF-TE is used in [GMPLS](https://en.wikipedia.org/wiki/GMPLS) networks as a means to describe the topology over which GMPLS paths can be established. GMPLS uses its own path setup and forwarding protocols, once it has the full network map.

In the [Resource Reservation Protocol](https://en.wikipedia.org/wiki/Resource_Reservation_Protocol) (RSVP), OSPF-TE is used for recording and flooding RSVP signaled bandwidth reservations for [label switched paths](https://en.wikipedia.org/wiki/Label_switched_path) within the link-state database.

### Optical routing

[RFC](https://en.wikipedia.org/wiki/RFC_(identifier)) [3717](https://tools.ietf.org/html/rfc3717) documents work in optical routing for IP based on extensions to OSPF and IS-IS.[[21]](https://en.wikipedia.org/wiki/Open_Shortest_Path_First#cite_note-21)

### Multicast Open Shortest Path First

The Multicast Open Shortest Path First (MOSPF) protocol is an extension to OSPF to support multicast routing. MOSPF allows routers to share information about group memberships.

## OSPF in broadcast and non-broadcast networks

In broadcast multiple-access networks, neighbor adjacency is formed dynamically using multicast hello packets to *224.0.0.5*. A DR and BDR are elected normally, and function normally.

For [non-broadcast multiple-access networks](https://en.wikipedia.org/wiki/Non-broadcast_multiple-access_network) (NBMA), the following two official modes are defined:[[1]](https://en.wikipedia.org/wiki/Open_Shortest_Path_First#cite_note-rfc2328-1)

* non-broadcast
* point-to-multipoint

Cisco has defined the following three additional modes for OSPF in NBMA topologies:[[22]](https://en.wikipedia.org/wiki/Open_Shortest_Path_First#cite_note-22)

* point-to-multipoint non-broadcast
* broadcast
* point-to-point

## Notable Implementations

* [Allied Telesis](https://en.wikipedia.org/wiki/Allied_Telesis) implements OSPFv2 & OSPFv3 in Allied Ware Plus (AW+)
* [Arista Networks](https://en.wikipedia.org/wiki/Arista_Networks) implements OSPFv2 and OSPFv3
* [BIRD](https://en.wikipedia.org/wiki/Bird_Internet_routing_daemon) implements both OSPFv2 and OSPFv3
* [Cisco IOS](https://en.wikipedia.org/wiki/Cisco_IOS)
* [Cisco Meraki](https://en.wikipedia.org/wiki/Cisco_Meraki)
* [D-Link](https://en.wikipedia.org/wiki/D-Link) implements OSPFv2 on Unified Services Router.
* [Dell's FTOS](https://en.wikipedia.org/wiki/Force10_Networks) implements OSPFv2 and OSPFv3
* [ExtremeXOS](https://en.wikipedia.org/wiki/ExtremeXOS)
* [GNU Zebra](https://en.wikipedia.org/wiki/GNU_Zebra), a [GPL](https://en.wikipedia.org/wiki/GNU_General_Public_License) routing suite for [Unix-like](https://en.wikipedia.org/wiki/Unix-like) systems supporting OSPF
* [Juniper Junos](https://en.wikipedia.org/wiki/Juniper_Junos)
* [NetWare](https://en.wikipedia.org/wiki/NetWare) implements OSPF in its Multi Protocol Routing module.
* [OpenBSD](https://en.wikipedia.org/wiki/OpenBSD) includes [OpenOSPFD](https://en.wikipedia.org/wiki/OpenOSPFD), an OSPFv2 implementation.
* [Quagga](https://en.wikipedia.org/wiki/Quagga_(Software)), a fork of [GNU Zebra](https://en.wikipedia.org/wiki/GNU_Zebra) for [Unix-like](https://en.wikipedia.org/wiki/Unix-like) systems
* [XORP](https://en.wikipedia.org/wiki/XORP), a routing suite implementing RFC2328 (OSPFv2) and RFC2740 (OSPFv3) for both IPv4 and IPv6
* [Windows NT 4.0](https://en.wikipedia.org/wiki/Windows_NT_4.0) Server, [Windows 2000](https://en.wikipedia.org/wiki/Windows_2000) Server and [Windows Server 2003](https://en.wikipedia.org/wiki/Windows_Server_2003) implemented OSPFv2 in the [Routing and Remote Access Service](https://en.wikipedia.org/wiki/Routing_and_Remote_Access_Service), although the functionality was removed in [Windows Server 2008](https://en.wikipedia.org/wiki/Windows_Server_2008).

## Applications

OSPF is a widely deployed routing protocol that can converge a network in a few seconds and guarantee loop-free paths. It has many features that allow the imposition of policies about the propagation of routes that it may be appropriate to keep local, for load sharing, and for selective route importing. IS-IS, in contrast, can be tuned for lower overhead in a stable network, the sort more common in ISP than enterprise networks. There are some historical accidents that made IS-IS the preferred IGP for ISPs, but ISPs today may well choose to use the features of the now-efficient implementations of OSPF,[[23]](https://en.wikipedia.org/wiki/Open_Shortest_Path_First#cite_note-23) after first considering the pros and cons of IS-IS in service provider environments.[[24]](https://en.wikipedia.org/wiki/Open_Shortest_Path_First#cite_note-24)

OSPF can provide better load-sharing on external links than other IGPs.[[*citation needed*](https://en.wikipedia.org/wiki/Wikipedia:Citation_needed)] When the default route to an ISP is injected into OSPF from multiple ASBRs as a Type I external route and the same external cost specified, other routers will go to the ASBR with the least path cost from its location. This can be tuned further by adjusting the external cost. If the default route from different ISPs is injected with different external costs, as a Type II external route, the lower-cost default becomes the primary exit and the higher-cost becomes the backup only.

The only real limiting factor that may compel major ISPs to select IS-IS over OSPF is if they have a network with more than 850 routers.[[*citation needed*](https://en.wikipedia.org/wiki/Wikipedia:Citation_needed)]

## See also

* [Fabric Shortest Path First](https://en.wikipedia.org/wiki/Fabric_Shortest_Path_First)
* [Mesh networking](https://en.wikipedia.org/wiki/Mesh_networking)
* [Route analytics](https://en.wikipedia.org/wiki/Route_analytics)
* [Routing](https://en.wikipedia.org/wiki/Routing)
* [Shortest Path Bridging](https://en.wikipedia.org/wiki/Shortest_Path_Bridging)
* [Shortest path problem](https://en.wikipedia.org/wiki/Shortest_path_problem)

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  [*"Stub Area Design Golden Rules"*](https://web.archive.org/web/20000831182105/http:/www.groupstudy.com/bookstore/samples/thomas/). Groupstudy.com. Archived from [*the original*](http://www.groupstudy.com/bookstore/samples/thomas/) on August 31, 2000*. Retrieved November 30, 2011*.. Note: This is not necessarily true. If there are multiple ABRs, as might be required for high availability, routers interior to the TSA will send non-intra-area traffic to the ABR with the lowest intra-area metric (the "closest" ABR) but that requires special configuration.

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## External links

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 [Cisco OSPF](https://www.cisco.com/c/en/us/products/ios-nx-os-software/open-shortest-path-first-ospf/index.html)

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# Networking Basics: OSPF Protocol Explained

Photo: [Kai Schreiber](http://www.flickr.com/photos/genista/5731005) on Flickr

Open Shortest Path First (OSPF) is a standard routing protocol that’s been used the world over for many years. Supported by practically every routing vendor, as well as the open source community, OSPF is one of the few protocols in the IT industry you can count on being available just about anywhere you might need it.

Enterprise networks that outgrow a single site will often use OSPF to interconnect their campuses and wide area networks (WANs).

If you’re considering a dynamic routing protocol because your network has outgrown static routes, OSPF might seem a little daunting. It’s not quite as easy to [set up as EIGRP](http://www.auvik.com/media/blog/first-deployment-eigrp/) so the temptation might be to simply use EIGRP and avoid the intimidating terminology that comes along with a complete understanding of OSPF.

My recommendation is not to let OSPF scare you. It’s true that OSPF in large implementations can be complex. However, an OSPF configuration supporting smaller networks can be comparatively simple.

In this post, I’ll discuss some of OSPF’s major principles, and then follow up with a simple configuration that brings up OSPF between two Cisco routers and exchange routes.

## OSPF’s big idea

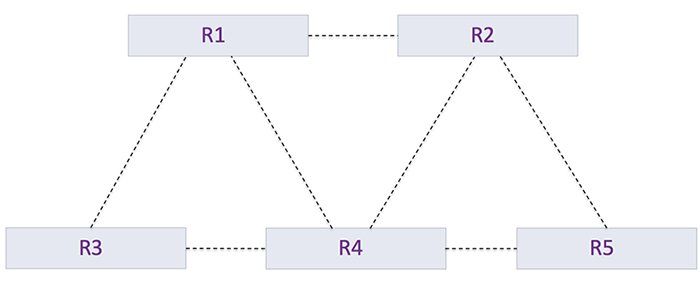
OSPF is a routing protocol. Two routers speaking OSPF to each other exchange information about the routes they know about and the cost for them to get there.

When many OSPF routers are part of the same network, information about all of the routes in a network are learned by all of the OSPF routers within that network—technically called an **area**. (We’ll talk more about area as we go on).

Each OSPF router passes along information about the routes and costs they’ve heard about to all of their adjacent OSPF routers, called **neighbors**.

OSPF routers rely on **cost** to compute the shortest path through the network between themselves and a remote router or network destination. The shortest path computation is done using [Djikstra’s algorithm](http://en.wikipedia.org/wiki/Dijkstra's_algorithm). This algorithm isn’t unique to OSPF. Rather, it’s a mathematical algorithm that happens to have an obvious application to networking.

Consider a simple example of five routers connected as shown in the diagram below. Assuming all links have the same cost, what’s the fastest way for R3 to connect to R5? Through R4 — R4 is the lowest cost path. (R3’s path to R5 via R1, for example, adds another link and therefore additional cost.)

[](http://www.auvik.com/wp-content/uploads/2014/11/ospf-protocol-routing-example.jpg)

## OSPF interfaces

Another important idea in OSPF is that interfaces used to exchange information with OSPF neighbors have different types. There are too many types to discuss here but you should be aware of two important ones.

1. An OSPF **broadcast** interface is connected to a shared network, like Ethernet.
2. An OSPF **point-to-point** interface is connected to a link where there can only be a single OSPF router on either end, such as a WAN link or a purpose-built Ethernet link.

The reason for the various interface types is to make sure that all routers know about all routes from all other routers.

On point-to-point links, there’s no mystery — the two routers know they’re the only OSPF routers on the link and so they exchange routes with each other.

On broadcast links, there’s a potential for many different OSPF routers to be on the network segment. To minimize the number of neighbor relationships that form on broadcast links, OSPF elects a **designated router** (as well as a backup) whose job it is to neighbor with all other OSPF routers on the segment and share everyone’s routes with everyone else.

## OSPF areas

Areas in OSPF are collections of routers grouped together. With the exception of **area border routers**, OSPF routers in one area don’t neighbor with routers in other areas. Among other reasons, areas were once used to scale large OSPF networks.

Back when router CPUs were less powerful than they are today, a general rule of thumb was to keep an OSPF area to no more than 50 routers. That would keep the number of OSPF shortest path computations and database updates to a manageable amount as interfaces went up and down, routes were learned and withdrawn, and so on.

In modern networks, it’s not unheard of to scale to a thousand routers or more in a single area — router CPUs have come a long way.

Today, although scale is not much of a reason for implementing multiple areas, OSPF areas are still useful as administrative boundaries in a network. For example:

* Route summarization & aggregation (replacing several small routes with one larger route that covers them) can only happen at OSPF area boundaries.
* Not all routers need to know about every other route available in a network. Using OSPF areas, it’s possible to inject a default route representing all routes outside of the local area.

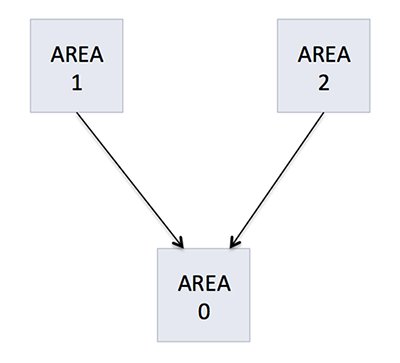
If you’re thinking you should be able to summarize or filter routes between OSPF routers within an area, the problem is that for the shortest path first (SPF) calculation to work, all routers in an area need to have an identical “picture” of the network. Therefore, it’s impossible to hide routes between OSPF routers in an area.

(A type of OSPF filtering you might be familiar with is actually a filter between the OSPF routing information base (RIB) and the router’s forwarding information base (FIB). The local OSPF process still passes information about the filtered route along to other OSPF neighbors.)

The most important area in OSPF is the **backbone** area, also known as area 0. The backbone area is the area that all OSPF areas must traverse to get to other OSPF areas.

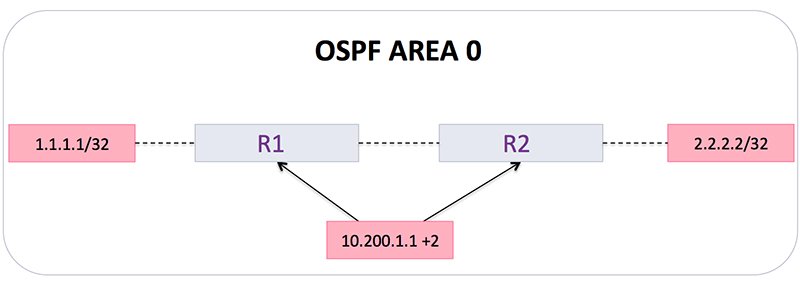
For instance, let’s say we have area 0, area 1, and area 2. Area 1 traffic must traverse area 0 to get to area 2, and vice versa. Even if there was a router with one interface in area 1, and another interface in area 2, area 1 and 2 traffic could not traverse this router directly. The reason for this is loop prevention.

While OSPF routers within an area know everything there is to know about the network topology, topology information is hidden at area borders. For more detail about why the backbone area and related traversal rule exists, network architect [Jeff Doyle has an article that explains it well](http://www.networkworld.com/article/2348778/cisco-subnet/my-favorite-interview-question.html).

[](https://www.auvik.com/wp-content/uploads/2014/11/ospf-protocol-backbone-area-routing.jpg)

## A simple two-router OSPF network

Here’s an example of a network configuration that creates a very simple OSPF network between two Cisco routers. The routers are placed in area 0 and an OSPF point-to-point link is configured between them. R1 will announce the 1.1.1.1/32 route and R2 will announce 2.2.2.2/32. Let’s walk through it.

[](https://www.auvik.com/wp-content/uploads/2014/11/ospf-protocol-area-0-network-routing.jpg)

### R1’s configuration

interface Loopback0

ip address 1.1.1.1 255.255.255.255

!

interface GigabitEthernet2

description OSPF Transit

ip address 10.200.1.1 255.255.255.252

! Set this interface type to be “point to point”. Put another way, there will be no “designated router” on this segment.

ip ospf network point-to-point

!

! Start an OSPF process with an ID of 200. This process number isn’t super important -- both sides do \*not\* have to match. The process ID distinguishes it from other OSPF processes you might be running on your router.

router ospf 200

! If you don’t set an OSPF router ID, the router will choose the highest IP of a loopback interface. If there are no loopback interfaces, the highest IP assigned to any router interface will be chosen. If you change the router ID, you’ll have to clear the OSPF process for it to become active, briefly knocking down OSPF adjacencies with neighbors.

router-id 10.200.2.1

! As OSPF neighbors communicate, details are logged. Can be helpful in troubleshooting OSPF adjacency issues.

log-adjacency-changes detail

! Place any interface with an IP address matching 1.1.1.1/32 into OSPF area 0. This line will match interface Loopback0 on this router.

network 1.1.1.1 0.0.0.0 area 0

! Place any interface with an IP address matching 10.200.1.0/30 into OSPF area 0. This line will match interface GigabitEthernet2 on this router.

network 10.200.1.0 0.0.0.3 area 0

### R2’s configuration

interface Loopback0

ip address 2.2.2.2 255.255.255.255

!

interface GigabitEthernet2

description OSPF Transit

ip address 10.200.1.2 255.255.255.252

ip ospf network point-to-point

!

router ospf 200

router-id 10.200.1.2

log-adjacency-changes detail

network 2.2.2.2 0.0.0.0 area 0

network 10.200.1.0 0.0.0.3 area 0

## Basic OSPF commands

Now that OSPF is configured, let’s look at a few basic OSPF commands available on Cisco IOS and similar industry-standard CLIs. I’ve truncated some of the command output to make it easier to read and explain.

The command “show ip ospf neighbor” displays OSPF neighbors and their state. In this case, we see R1 and R2 fully adjacent to each other via their GigabitEthernet 2 interfaces.

The **neighbor ID** equals the router ID of the neighbor.

The **priority** is related to the election of a designated router — not important for our simple example.

On a point-to-point link, the OSPF **state** should be “full.” If it’s not, something has probably gone wrong.

The **dead time** is a countdown timer constantly being reset as messages are heard from the neighbor. If the dead time gets to zero, the neighbor is presumed dead, the adjacency is torn down, and the link removed from SPF calculations in the OSPF database.

R1#show ip ospf neighbor

Neighbor ID Pri State Dead Time Address Interface

10.200.1.2 0 FULL/ - 00:00:33 10.200.1.2 GigabitEthernet2

R1#

R2#show ip ospf neighbor

Neighbor ID Pri State Dead Time Address Interface

10.200.2.1 0 FULL/ - 00:00:30 10.200.1.1 GigabitEthernet2

R2#

When looking at a device’s forwarding table, the “show ip route ospf” shows just the routes that have entered the forwarding table via OSPF.

In our case, R1 will know the 2.2.2.2/32 route via OSPF, while R2 will know 1.1.1.1/32 via OSPF. Why doesn’t the 10.200.1.0/30 route show up as an OSPF route on either R1 or R2? Because 10.200.1.0/30 is also a **connected route**. Connected routes trump OSPF learned routes.

R1#show ip route ospf

2.0.0.0/32 is subnetted, 1 subnets

O 2.2.2.2 [110/2] via 10.200.1.2, 00:43:45, GigabitEthernet2

R1#

R2#show ip route ospf

1.0.0.0/32 is subnetted, 1 subnets

O 1.1.1.1 [110/2] via 10.200.1.1, 00:44:13, GigabitEthernet2

R2#

## Helpful OSPF guides

There’s a lot more information about OSPF than we can explore in a blog post. In fact, entire books have been written on the topic. My hope is that your curiosity has been piqued to go exploring and learn more.

Over my years of operating OSPF networks, there are certain references I’ve referred to repeatedly. I hope they help you as much as they’ve helped me.

* [Open Shortest Path First](http://en.wikipedia.org/wiki/Open_Shortest_Path_First) (Wikipedia)
* [OSPF Design Guide](http://www.cisco.com/c/en/us/support/docs/ip/open-shortest-path-first-ospf/7039-1.html) (Cisco)
* [OSPF Neighbor States](http://www.cisco.com/c/en/us/support/docs/ip/open-shortest-path-first-ospf/13685-13.html) (Cisco)
* [OSPF Neighbor Problems Explained](http://www.cisco.com/c/en/us/support/docs/ip/open-shortest-path-first-ospf/13699-29.html) (Cisco)
* [Troubleshooting OSPF](http://www.cisco.com/c/en/us/support/docs/ip/open-shortest-path-first-ospf/12151-trouble-main.html) (Cisco)